

**JOURNAL OF THE**  
**BOSTON SOCIETY**  
**OF**  
**CIVIL ENGINEERS**

**SEPTEMBER, 1926**

**Featuring**

**Bridge Maintenance**

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**Engineering of the  
Modern Airplane**



**Vol. XIII**

**No. 7**

# BOSTON SOCIETY OF CIVIL ENGINEERS

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# JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

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## BRIDGE MAINTENANCE

BY BENJAMIN W. GUPPY, MEMBER, BOSTON SOCIETY OF CIVIL ENGINEERS\*

(Presented before the Designers Section, B. S. C. E., May 12, 1926)

THE reason for this talk is that nothing on this earth is permanent. Our structures begin to wear out even before they are completed. Hence the necessity for *maintenance*.

The reasons for this depreciation are many. Our inspectors are instructed to make a careful examination of all structures supporting tracks or over the tracks to ascertain any damage or deterioration caused by derailments or collisions; by objects falling off of or being dragged along under cars; by ice and drift at high water or by other objects passing under the structure; by falling trees, poles or boulders; by landslides; by lightning, fire, frost or tornadoes; by undermining or settlement of the foundations or other supports or other movement of the masonry; by rust, decay or the action of animals or marine worms; by poor design, workmanship or materials; by overloading, neglect or abuse; or by ignorant or malicious persons.

And the structures survive!

How far can this depreciation go before repairs are necessary? In other words, what *Margin for Depreciation* has the structure? The entire question of maintenance depends upon this margin. It is measured by the difference between the unit stresses under load and the maximum unit stresses that your conscience allows you to use.

A structure designed with low unit stresses has a large "margin for depreciation," but with high unit stresses the margin is small. Increase the load on the structure and you reduce the margin. When the margin becomes zero, 100 per cent maintenance is required. While this may be possible it is not practical, either physically or financially. Moreover, a reduced margin for depreciation calls for more frequent inspection and repairs. Engineers unaccustomed to maintenance do not appreciate this. For example: We maintain a certain highway bridge over one of

\* Engineer of Structures, Boston & Maine Railroad, General Office Building, Lechmere Square, Cambridge, Mass.

our main lines. The bridge was built under a decree specifying loads and unit stresses. This gives us a definite margin for depreciation. The location and design of the bridge are such that the floor requires a thorough overhauling every eight or ten years. This requires taking up the pavement and waterproofing on the roadway every time repairs are made. The Street Railway Company operating over this bridge wished to run heavier cars. Its consulting engineer figured the stresses under this increased load and decided it was safe to run the cars, and so it was as long as maintenance was 100 per cent perfect. We called his attention to the fact that the margin for depreciation would be reduced to practically nothing, and that we would be obliged to make repairs more frequently than heretofore, and we felt we should receive some compensation. He frankly admitted that he had never considered the subject from that point of view, and there might be something in it. I am glad to state that after mature deliberation he recommended and the street railway company agreed to pay for strengthening sufficient to give the existing margin under the heavier loading. I have dealt upon this "margin for depreciation" at some length because I wish you to realize the importance of the subject, and I look askance at the present tendency to boost the stresses used in design to obtain a small saving in first cost.

The operations of maintenance can be grouped under four heads: Inspection, Reports, Repairs, and Records.

### INSPECTION

The inspection is for the purpose of obtaining a record of the present condition and safety of a structure, and to ascertain what changes have occurred since the preceding inspection and the necessity for repairs. The frequency of inspections is determined by the condition and "margin for depreciation" of the structure. All of our bridges are inspected annually. Some require inspection monthly, quarterly or semi-annually.

The track walker on his daily round looks for damage from external causes. The section crews look out for ties and floor plank, making emergency repairs when necessary. Divers are employed after freshets to determine damage under water, and at stated intervals to determine the action of sea worms on piling. Reference points are established on defective masonry and check measurements taken at stated intervals to determine progressive movement, the inspectors acting under the following instructions.

*Special Inspections.* — Special inspections shall be made and check measurements taken as directed. When check measurements are



required once a year only they shall be taken at the time of the annual inspection. When special inspections or check measurements are required once every six months they shall be made each spring and fall when structure is free from snow and ice. If required at more frequent intervals they shall be made regardless of the season. Check measurements to determine forward movement of abutments shall be made from abutment to abutment and not to any temporary bent that may be liable to be displaced. (This has actually happened.) Reference points shall be permanently located and locations accurately described in first set of notes forwarded. In order to determine if repairs to masonry structures are effective, check measurements shall be continued, locating new reference points if necessary, until instructions are received to discontinue.

If instrumental work is necessary the Division Engineer furnishes a party which works under the direction of a draftsman from headquarters.

In addition to his kit and report blanks each inspector is provided with:

- 1 copy of the Rules and Regulations of the Operating Department.
- Bridge list covering the inspector's territory.
- List of main line wooden stringers and trestles showing stresses and permissible depreciation, and a diagram showing loss in strength of timber stringers of different depths for each inch loss in depth by decay.
- List of bridges temporarily horsed showing restrictions to be placed in case bents are displaced.
- List of sidetrack bridges giving maximum allowable loads.
- List of overhead bridges giving posted capacities.
- List of overhead wire crossings.
- List of roofs to be inspected.
- List of structures requiring special inspections and check measurements.
- A copy of the "Maximum Weight and Clearance Chart" showing maximum engine and carloads permitted on the various lines of the system.
- A set of prints showing faulty details.

The inspector is required to study these prints showing faulty details in order to recognize such poor details and know where to expect failure. (These sketches are included elsewhere in this article.)

### REPORTS

The report furnishes to the officials interested the information obtained by the inspection. When a man has charge of several thousand structures with inspectors scattered over a wide territory he must have assurance that no part of the structure has been overlooked, so the inspector is required to report the good as well as the bad in order that the

condition of the structure may appear in the records, and, in order to insure uniformity, standard forms are used in accordance with instructions furnished.

Our "Rules for the Guidance of Bridge Inspectors" now consists of a pamphlet of thirty-six pages covering general instructions, details in regard to inspection of existing structures, shop inspection of fabrication, field inspection of erection of metal structures, and inspection of field painting.

Two forms are used for reporting the results of the inspection, — the bridge inspection book, in which everything is entered, and the current bridge inspection report. In the bridge inspection book (Table 1) the printing is only on the left margin of the left-hand page with five columns for recording. The current bridge inspection report, or C. B. I. R. (shown in Table 2) is used for reporting work necessary during the current year and the year following. By reporting work required for two years the reports are both a check on current year's maintenance program, and on December 1 the C. B. I. R. "jack up" file automatically becomes the basis for preparing the maintenance budget for the following year. The inspection books are sent to headquarters as soon as work on any line or branch has been completed or the book has been filled. The notes are copied in the office records, and the books sent to the Supervisor of Bridges and Buildings.

TABLE 1. — ITEMS INCLUDED IN BRIDGE INSPECTION BOOK,  
BOSTON & MAINE RAILROAD

|                            |                             |
|----------------------------|-----------------------------|
| 1. Date.                   | 20. Top Bracing.            |
| 2. Division.               | 21. Bottom Bracing.         |
| 3. Mile.                   | 22. Sway Bracing.           |
| 4. Name.                   | 23. Wall Plate or Pedestal. |
| 5. Span.                   | 24. Expansion Joint.        |
| 6. Rails.                  | 25. Bearings.               |
| 7. Ties.                   | 26. Masonry.                |
| 8. Guards.                 | 27. Caps.                   |
| 9. Stringers.              | 28. Piles or Post.          |
| 10. Stringer Connections.  | 29. Sills.                  |
| 11. Floor Beams.           | 30. Bracing of Bents.       |
| 12. Floor Beam Connection. | 31. Line.                   |
| 13. Girders.               | 32. Camber.                 |
| 14. Top Chord.             | 33. Paint.                  |
| 15. Bottom Chord.          | 34. Miscellaneous.          |
| 16. Ties on Rods.          | 35. Recommendations.        |
| 17. Posts.                 | 36. Inspector.              |
| 18. Truss Joints.          | 37. Action by Supervisor.   |
| 19. Drain Holes.           |                             |



TABLE 2

## Boston and Maine Railroad

.....DIVISION

*Current Bridge Inspection Report*

I have this day inspected.....  
 at .....  
 and found its condition as follows:.....  
 .....  
 .....  
 .....  
 .....  
 .....

The following work is required within.....months to  
 maintain structure in good condition: .....  
 .....  
 .....  
 .....  
 .....

The following work must be done within .....months to keep  
 the structure safe: .....  
 .....  
 .....  
 .....  
 .....

Date.....192.....

NOTE. — This report to be used in addition to the entry in inspection book, whenever any work is required on the structure within twelve months. Make separate report on each structure requiring repairs and send to Supvr. B. & B. and Engineer of Structures each day. In case dangerous conditions are found report by telegraph to Supvr. B. & B., Engineer of Structures and Division Superintendent. Unless renewal is recommended, give bill of material required for repairs on back of report, and mark plainly with yellow chalk corresponding pieces of structure.

The C. B. I. R.'s are made in triplicate by the inspector and copies sent to the Engineer of Structures and Supervisor of Bridges and Buildings. The reports that reach our office are copied on the yellow sheets, four carbons being made. One of these yellow sheets is pinned to the original and placed in the file. This is our record that the report has been studied and proper action taken. A second copy is appropriately dated and placed in the C. B. I. R. "jack up" file. At the proper time an inquiry is sent the Division Engineer regarding the status of repairs recommended. The extra copies of the yellow sheets are sent to the Division Engineer who hands one copy to Supervisor of Bridges and

Buildings. This checks receipt of original C. B. I. R. sent by the Inspector to the Supervisor. If the Supervisor does not receive the yellow sheet within a reasonable time after he has received the original he notifies headquarters. This checks receipt of original at our office. If both originals happen to get lost in transit (which has not yet happened) the recommendation for repairs still appears in the inspection book. We think we have this question of recommendation for repairs so well checked that there can be no excuse for the work being overlooked. The Division Engineer forwards a completion report as soon as repairs have been made.

Repairs are made either to restore the structure to its original strength or to keep it safe until it can be renewed or given a thorough overhauling.

### REPAIRS

The following extract from our "Instructions to Draftsmen" covers the preparation of plans for repairs.

#### REPAIRS TO EXISTING STRUCTURES

The draftsman assigned to the work shall visit the structure with the division inspector and make a thorough personal examination of the entire structure to check the inspector's report. All defects found, no matter how slight, shall be accurately located and fully described. When plans of structure are available, blue prints shall be taken along and defects noted directly on same.

Otherwise sketches and measurements shall be made in sufficient detail to show nature and extent of defects and for purpose of preparing plans for repairs.

In general, repairs are required on account of —

- (a) Loss of section by corrosion.
- (b) Damage due to external forces.
- (c) Faulty detailing.

Members or parts of members shall be replaced or reinforced as best suits each case. When repairs are required on account of faulty detailing, the repairs shall be planned to correct original faults and avoid repetition of failure.

In all cases the detailing shall be such that the metal applied for the purpose of making repairs will receive and transmit its full share of stress.

#### *Information to be given on Drawings*

- (1) General plan locating points where repairs are required.
- (2) Details showing size and make-up of various parts, shop and field rivets, and drilling and cutting required in the field.
- (3) Schedule of material, including field rivets.
- (4) Statement of manner of carrying out the work, and sequence of the various operations.
- (5) Sketches of necessary falsework.

Drawings submitted for approval shall be accompanied by an estimate of man days to complete the work and an estimate of the cost of making repairs, and if this

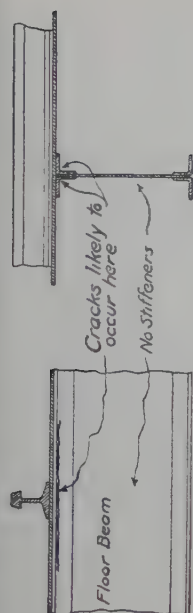
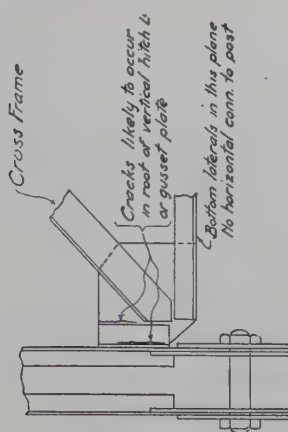
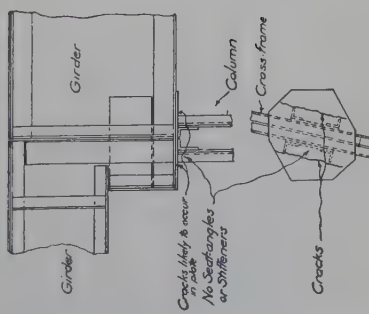
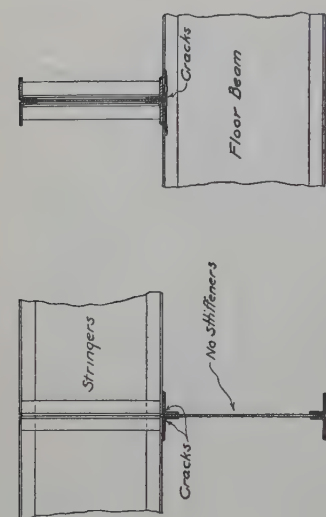
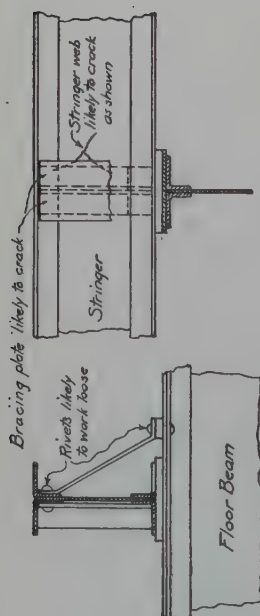
*Solid Plate Floor**Cross Frame connection to Post of Pin-connected Deck Truss*

FIG. 1.—SKETCHES OF FAULTY DETAIL  
Failure likely to occur as indicated





Stringers resting on Floor Beam.



Stringers resting on Floor Beam

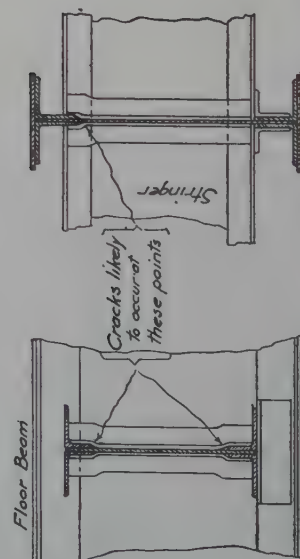
Stringer connecting to Web of Floor Beam when Hitch L<sub>2</sub> of Stringer are crimped over Flange L<sub>1</sub>

FIG. 2. — SKETCHES OF FAULTY DETAIL

Failures likely to occur as indicated

exceeds 10 per cent of the cost of the structure, an estimate also of renewal in accordance with existing standards. Take notes at structure at time of making inspection to provide for this so that second visit will not be needed.

The work must be planned and executed so that traffic may be safely maintained on the railway, and, as far as practicable, on any highway involved.

The material shall be ordered shop riveted so far as the same will not interfere with the ease of erection in field. When detailed shop drawings of structure are available, holes for field rivets may be ordered punched  $\frac{1}{8}$ " small at shop and reamed to match in field, otherwise holes for field rivets shall be drilled in field. Shop drawings must be checked with structure before ordering material.

The record of the repairs to metal bridges is kept on a form with the following headings: Date reported, check inspection, starting and completion of plans, plans and requisition sent out, material shipped and received, work started and completed. The crews report to the Supervisor of Bridges and Buildings of the division on which they are working. A system map with the location of the repair jobs spotted on in color is a great aid in routing the bridge crews, but emergency jobs are liable to create havoc with our program.

#### RECORDS

The records are for the purpose of keeping the accumulated information in a readily accessible form.

The records are kept on loose leaf sheets and the original papers in the file. Each structure has a separate page in the record book and a separate folder in the file.

The record book contains, in addition to inspection notes, a brief description and history of the bridge, reference to laws, ordinances, decrees or licenses under which built, notes in regard to joint maintenance, stresses under heaviest loads on line, maximum engine and car capacities, records of repairs and painting and file numbers of plans.

Such, briefly, is the method of maintenance followed on the Boston & Maine Railroad.

The methods of a consulting engineer who only occasionally inspects and reports on a structure will not have to be so elaborate, but he will have to work to the same end, — namely, to determine the present condition and margin for depreciation of the structure.

This will require a thorough examination of the structure, a checking of existing plans against the structure or measurement of the structure in detail, the determination of areas of cross section of members as reduced by depreciation, and the computation of stresses under maximum loading.

With this information a plan for necessary repairs can be prepared.

## FAULTY DETAILS

The drawings of faulty details, indicating various failures, are shown in the accompanying figures.

Irrespective of the design of the bridge the following parts require careful scrutiny.

Hitch angles are liable to split along root or crack across through the rivet holes.

Flanges (without cover plates) may have split angles and rivets working on web.

Truss members may be cracked and have loose rivets in connections. When a riveted member has been damaged by a blow there will be injury at the point of impact and more than likely split metal at the joints. So examine the member carefully for its entire length.

Setting up a vibration in an eye bar by shaking it is not necessarily a sign of looseness. If the bar is loose it will either move on the pin or else chatter. If very loose it should be tested under live load to see if it is carrying any. Corrosion is liable to occur any place where paint is poor, but especially where there is a chance for dirt to collect, where members catch brine dripping and over tracks.

Masonry may fail by sliding, tipping, settling or disintegrating, usually accompanied by the development of cracks.

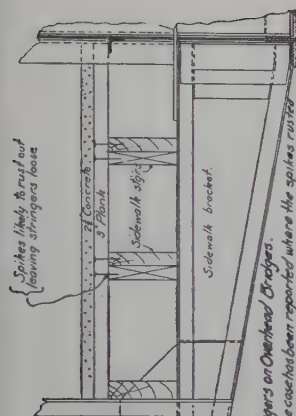
Be sure to have everything uncovered and examined that has been covered. Don't think that anything that is covered up can be neglected. You will almost always find trouble in such a place.

Also *keep your head*. Don't magnify small defects and wave the red flag unnecessarily. Think things over carefully, reason out the cause of the trouble and the effects of same and then *play safe*.

The education of a structural engineer is not complete until he has had a certain amount of experience in maintenance, and the earlier this occurs in his career the better, as no design can be entirely satisfactory unless due provision has been made for the requirements of maintenance.

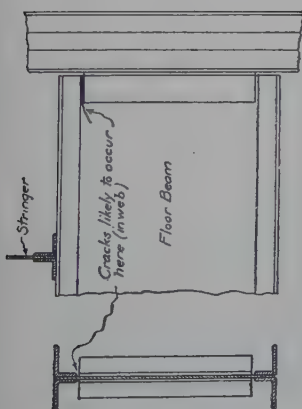
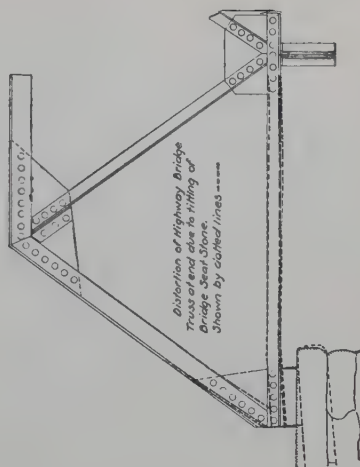
The life of a bridge inspector contains a reasonable amount of danger and hardship, but should prove attractive to a lover of an outdoor life. The attitude of a bridge inspector toward his job may be found in the following notes written by an assistant bridge inspector in 1916 and found in the division office several years after his death.





### Stringers on Overhead Bridges.

One coach has been reported where the spikes rusted out and blew from locomotive moving stringer sufficiently to cause it to fall on a passing train. Bear this accident in mind when inspecting overhead structures.



Floor Beam Framing to Col., Truss Post, or Girder when connection is to not pass over Floor Beam Flange Ls

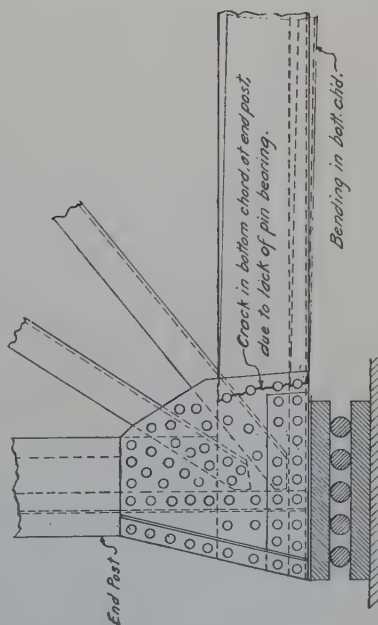


FIG. 3. — SKETCHES OF FAULTY DETAIL  
Failures likely to occur as indicated

## BRIDGE INSPECTING

*By Joseph S. Guppy*

The conception of the duties of a bridge inspector is probably rather vague to many; nevertheless, they form a definite cog in the wheel of the system.

Since the bridges occupy a position toward traffic similar to that of the mythological Atlas towards the Globe, it is evident that they must not be slighted, therefore for the bridge inspector. He and his assistant must make a minute inspection of each bridge in his territory at least once a year, looking especially for defective steel, rusted members, poor foundations, besides many other details. The word "looking" sounds easy but embodies many hazards; for instance, the inspector is obliged to go through an arch spanning a deep river. He builds a raft, but, due to his insufficient knowledge of naval architecture, the raft suddenly obeys Newton's laws of gravitation when in the deepest part of the river, and Mr. Inspector calmly floats to shore. Or another case: he is obliged to swing beneath a girder to inspect the bearings. After grasping the bottom flanges of the girder firmly he negotiates the swing. Very good, but he is now in a position from which it requires ingenuity galore to extricate himself, so he hangs on the flange with his teeth, ties a long lock of hair to a rivet head for safety, swings his legs over a cross frame (that's what he would like to do) and he's up again. Besides these pleasures the inspector has little sojourns on his motor car. These are fine on an abandoned side track, but on the main line dodging fast extras it's no place for a nervous man.

Still the bridge inspector doesn't appear as if he had lost much sleep or his appetite; in fact, quite the contrary, and he endeavors to adhere strictly to his motto taken from the Latin (a motto which every man that works on the right of way might follow) "*Nota Bene*" or, in English, "Be Observing."

## Discussion

LEWIS E. MOORE.\* No one is better qualified to speak on the subject of maintenance of bridges than the speaker to whom you have just listened. He has dealt largely and thoroughly with the subject of maintenance and has illustrated certain faults in design which lead to deterioration. These last can readily be avoided by proper design.

Consideration of the subject of maintenance and deterioration leads us to another phase of the question. Deterioration means renewal sooner or later, and that opens up at once the subject of designing so that unavoidable renewals may be made quickly and with as little interruption to traffic as possible. Bridges over steam railroads are particularly susceptible to rapid corrosion. The rate of this corrosion depends on the material, its clearance above the railroad (the lower it is the faster it depreciates), and upon its design. If designed so that the locomotive gases can collect in pockets under the floor the depreciation will be very rapid. Some think that covering the steel with concrete will protect it. So it does, for a time, but I question whether this protection is as permanent as some think it is. With low clearances

---

\* Consulting Engineer, Tremont Building, Boston, Mass.

and heavy traffic the concrete itself disintegrates and breaks off. Rusting of the steel inside the concrete breaks the latter off also. Once started it is almost impossible to patch it successfully.

Where concrete protection is used the amount of steel in the structure must be greatly increased to care for the added dead load. If the same amount of steel were used and the concrete omitted there would be a much larger margin for depreciation and the saving in first cost by omitting concrete might be enough to provide for a new structure when the first one required renewal.

The tendency now, however, is to design for permanency as far as possible. The method of protection used by the city of Boston at the present time is to suspend a solid ceiling of  $\frac{1}{2}$ -inch cast-iron plates under the bridge. These plates protect the concrete from the direct effects of the exhaust, and are used as a form for the concrete protection which is poured on top of them and around the steel girders.

This construction is the best we know of to-day, but is expensive. An alternative is to design a floor that can be quickly renewed when worn out, and to place the main girders so that they are above the floor level and therefore protected from corrosion.

Turning to highway bridges other than those over railroads the design should be such that dirt will not accumulate on the bridge seats or on other portions of the steel work. Cases have come under my notice where dirt has collected on the bottom flange of a plate girder to such an extent that the web rusted completely through for distances of 3 or 4 feet along the flange. A bridge seat can be kept clear of dirt by carrying the curb clear around the ends of the trusses. I have done this very successfully several times.

Another source of trouble on wooden decks is fires. This danger can often be obviated by very simple means. One bridge in this Commonwealth suffered greatly from this cause. The deck was wooden and there were heavy wooden curbs on each side of the roadway. Dirt and slivers of wood would collect against these curbs and a cigarette butt would do the rest. The wind blows very hard at this location most of the time, so the writer suggested about ten years ago that the curbs be raised on wooden blocks so that the wind blowing under them would keep the bridge free from dirt and débris. This was done and there has not been a fire on this bridge since.

In conclusion, — designing a bridge involves much more than merely making certain parts strong enough for certain loads. Attention must be paid to ease of maintenance, security from fire and accident, and to making the construction such that minimum delays to traffic will occur while the unavoidable work of maintenance is being prosecuted.



## THE ENGINEERING OF THE MODERN AIRPLANE

BY EDWARD P. WARNER\*

(Presented May 19, 1926)

I SUPPOSE that if a group of civil engineers had got together to hear a discussion of the status of the airplane twelve or fifteen years ago they would have come essentially as laymen, interested in a general way in all scientific development and in all inventive progress, but hearing of the airplane with no idea that it had any very direct contact with or bearing on their own professional work. But the aeronautic engineer is now able to meet with the civil engineer on a common ground, for if there is one single phrase in which we can sum up the change of outlook of those engaged in airplane design and production from 1915 to 1926, that phrase would be the statement that the design of the airplane has ceased to be purely an inventive art, that it has become progressively less an inventive art and more a branch of engineering science. So we have much in common as time goes on and the engineer discovers that some of his principles apply particularly and specifically and with special force to the airplane.

The airplane, by the very conditions under which it operates, includes hazards and special difficulties which can only be overcome in advance, or eliminated in the course of the work, by the application of engineering methods and scientific analysis.

In the early studies of the automobile it was possible to develop the structure of the car, to bring the frame, the steering gear, etc., up to the required standard, by a process of trial and error. The pioneers took a car and drove it on the road and tested it out for one mile or a hundred thousand miles, and if it did not come up to standard then they took it back to the shop and strengthened it. But if an airplane gives way in flight the same man seldom has an opportunity to try it again. At least this was true a few years ago. It is not so true now, for a reason that I will comment upon later.

---

\* Professor of Aeronautical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.; Assistant Secretary, United States Navy, Washington, D. C.

So in the first place analysis, and especially structural analysis, — the determination of loads falling on the various members of the structure, — was very significant and important. The airplane is not unique in that. As a matter of fact the collapse of a primary member of an airplane is not more serious than in the case of some other structures, and indeed is far less serious than the collapse of a bridge member, in actual loss of life.

But, there again, in contrast with the civil engineer in his more normal field of structural activity, the aeronautic engineer contends with special difficulties. One is that the structure is in some respects exceedingly complex. There is the consideration of a proper layout — one that will offer low air resistance. It often happens that a structure of the desired form becomes many-fold redundant. This is true of the airplane. Also, the types of combined stress encountered are very complex. Furthermore, whereas in the design of a bridge or building the weight is of course of some significance, as it is in any branch of engineering design, it is not anywhere nearly as significant as in airplane design, for the difference between a light and a heavy structure means the difference not only between ability to carry a large or a small payload in the commercial machines, but also the difference between ability to gain the necessary minimum of performance and inability to secure satisfactory performance with any useful load at all. Nearly everything in airplane design gets back to weight. All designers are struggling to save weight, and competition in this respect among the constructors has become increasingly keen. Each one has invoked some method of his own for economy in one part or another. The importance of that is perhaps most easily demonstrated by a calculation which relates weight saving to the purely economic problem of commercial aviation — the problem of traffic and cost. It has now become easy to operate over any favorably located route with extreme reliability. There is very small hazard to the passengers. With the airplane the passengers can be given travel as comfortable as by any means of surface transportation, in the opinion of a good many who have tried it. But the cost is necessarily high at the present time, and it is likely to remain up for some time to come. The problem of commercial aviation is one of cutting down the cost and of securing traffic, and traffic can only be secured by cutting down the cost. As long as you charge \$2 a ton-mile you will get a very limited amount of express and freight. If that can be cut to \$1.60 or \$1.40 a ton-mile — which is figured conservatively for the near future — the amount of “rush” express and special freight will corre-

spondingly increase, and that in itself will be favorable to further reduction of cost.

We find that the cost of operating the airplane at the present time divides into several parts, and we can set aside one of those as representing the part of the cost proportional to the total weight carried in the air, including the cost of fuel and oil and a few other things as well, — and this operating cost runs at present about 20 cents per ton-mile. There is no doubt that the airplane can be used more intensively than any other vehicle of land, air, or sea. It should be able to do about 80,000 miles of flying a year. I don't believe any motor bus or ship will touch that rate of performance. One machine of which record was kept did 19,000 miles of flying in one month, which was equivalent to about 1,000 miles every day except Sundays and foggy days. Taking that 80,000 miles a year and a cost of 20 cents per ton-mile, proportional to the weight carried, and allowing for depreciation, insurance, etc., we come to the conclusion that it is actually worth twenty dollars to save one pound in weight of an airplane. That is to say, by reducing the weight of an airplane structure one pound and increasing the cost by twenty dollars the increased carrying charge is just balanced by the decrease in operating cost through the year. For a freight car, as figured on the same basis, — although my figures for railroads are not as complete as for air lines, — it runs from 5 to 6 cents a pound. To make a concrete comparison, suppose we have steel at 10 cents a pound and duralumin at \$1 a pound, it would not even be worth while in a freight car to replace  $1\frac{1}{2}$  lbs. of steel with  $\frac{1}{2}$  lb. of duralumin if that were possible. In airplane design it would be worth while to replace 20 lbs. of steel by 19 lbs. of duralumin at an additional cost of \$17. That is what weight saving means to the airplane designer. And it is just as important in the military airplane as in the commercial. As a matter of fact, from the point of view of the pilot in time of war it is more important, because the difference between a heavy structure and a light one may mean the difference between satisfactory and unsatisfactory maneuver, and may mean the difference between being shot down and emerging a victor.

Finally, another factor of importance to the trained engineer in airplane design is the greatly increased scope of design which he must cover, whatever his training may have been. In 1915 an airplane was anything that flew, and there was not a great deal of difference in size, carrying capacity and speed. There were some racing machines with engines of very modest power. There were some machines which carried 2, 3 or 4 passengers. That has all been changed — to put it

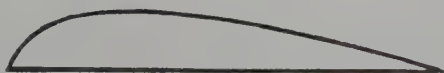


mildly. Whereas airplane sizes and types were almost standardized at the beginning of the war, from 1914 to 1918 during the war, and from experience since that time, there has been an enormous enlargement in range of activities both in sizes and in specialized types. One outstanding feature has been extreme specialization of function. The military airplane has become a flying battleship, designed with special reference to the military function it is to perform, with reference to the weight and bulk and to the properties of military equipment to be installed and the convenience of the pilot in operating. Similarly, the commercial airplane is specialized for flying by night, for flying over flat or over mountainous country, some for mail sacks, others for convenience and comfort in carrying passengers — all built along different and very individual lines.

Now, having said something of the present-day airplane in respect to its form and size, and its performance, I want to get back to its structure. I have already commented on the variety of structural possibilities. The problem of structural arrangement is partly structural and partly aerodynamic. You cannot use a wing of this section



and put all the bracing inside from the root of the wing to the tip; you have to get up to something like this



The structural efficiency is increased by increasing the depth of structure within the wing, but the wing is somewhat less efficient aerodynamically when you increase the thickness from 8 or 10 per cent of the chord to something like 20 per cent of the chord for maximum thickness. The mutual balance of various factors of merit must be given careful consideration in the design.

When stress analysis was first applied in airplane work it was simple enough. Bending and direct stresses were treated quite independently. Existing formulas were used for the design of spars and struts. The spars acted under direct bending and compression and the stresses were calculated by direct summation of compression due to direct loading and compression due to bending. But even before we can apply the simplest stress analysis we must know something about the loads. For a good many years our knowledge in this respect was grievously in arrears. We

had only a vague idea as to what would happen when flying and how much the structure would carry. Theories had no application except in the simplest problems; they did not approximate the truth, but we have begun in the last six or eight years to have a pretty clear idea of what loads act on a structure under varying conditions.

In the first place, mathematical analysis has been carried to a very advanced point in determining how the pressures are distributed over the various parts of the aeroplane under various flight conditions, and instruments have been devised for measuring loads directly in flight. You can't have acceleration without a change in load, so we use what we call an "accelerometer." It is a box about 8 inches long by 4 inches wide by 4 inches thick. This is taken for a ride, and the observer holds it in his lap. It contains a moving film and a light that flickers up and down with the acceleration of the airplane, parallel to its vertical axis, and makes a record. When you come down to earth you develop the film and have a chart showing how the load on the wings varied during the flight. So you can take up a pursuit machine and do loops and other stunts, and find the variation in the loads, and then design the next machine with greater uniformity of strength throughout the structure.

One development in airplane operating practice that has been peculiarly favorable to this sort of flight study has been the parachute, since of course no pilot wanted to overload his machine if structural collapse meant almost surely a fatal accident, and no one in charge of such experimental work would want to take the responsibility for such overloading. But with the parachute it is possible to get out. More than twenty pilots have been saved in this country so far by jumping from their machines when they caught fire or had collapsed structurally. Two men have each jumped twice. Passengers and pilots now always wear parachutes. In connection with a thesis at the Massachusetts Institute of Technology three years ago an army officer took an airplane up and made a series of dives, and each time after reaching a steady speed he would pull back and see how large a load he could get, and he did this at different speeds up to 160 miles an hour. That was as high as the air-speed meter went. The acceleration was then eight times gravity, which meant that his apparent weight was about  $\frac{3}{4}$  of a ton instead of 180 lbs. So he came down to the ground to get a 300-mile speed meter to continue the test, but he found the wings had failed. There was a bad crack across the wing, and the experiments had to be abandoned. That is the highest load yet measured.

The pursuit planes are now designed to carry an ultimate load of

twelve times their own weight before collapse. Observation machines are designed to carry eight times their own weight. In commercial flying they try to get a true factor of safety of about two, a strength twice what will ever be needed.

But that isn't all. After you have found the load the next question is to distribute it throughout the structure. The structures are often exceedingly complex, and they are liable to all kinds of secondary failure. We haven't as many redundances as we used to have, because the use of wires all over the machine formerly appeared almost at random. There was an old story during the war about a certain airplane, that the instructions given to the riggers were that after they thought that all of the wires were in place they should place a chicken inside the wing cell. If the chicken got out then they would know there was a wire missing. External drag wires and most other redundances are disappearing. We make up for that in some cases by the use of a covering for the wing and body which contributes to the strength. A very common practice in cantilever monoplanes has been to cover the wings with plywood.

Then there is the problem of vibration or flutter. Your plane may be strong enough and still the wings may flutter. There was a mishap due to this a few years ago. It was the first case in which the parachute was used. A new pursuit machine, of the cantilever type, was being taken up. The pilot partly closed the throttle, and vibration began and the stick was jerked out of his hands and went back and forth across the cockpit. He couldn't get hold of it again and it kept hitting him, so he climbed up out of the cockpit and got out of the way. Observers on the ground reported that at the time he dived the wings were vibrating 4 feet vertically at the tips and the tail was at 45 degrees in torsion. That was primarily due to torsion of the wings. While the plywood covering doesn't increase flexural stiffness much it does increase the torsional rigidity. It has been proved in a Dutch experimental laboratory that other things being equal the torsional stiffness was increased 700 per cent by plywood. The torsional yield was reduced about six-sevenths. Now that is one of our problems — how to allow for the effect of the plywood covering, and, similarly, the corresponding effect of metal covering.

Another very serious problem is that of combined bending and compression. That of course is a type of loading with which the civil engineer is not unfamiliar, but we get it in its worst form. We very commonly have beams continuous over three or more supports and a compression which varies along the beam. We get bays of different lengths and varying spars. That makes a very nice little problem in analysis. Aeronautic science can take to itself credit for the development



of more accurate methods of analysis, which are likely to prove of use outside the aeronautic art. In the past few years in Germany and England there has been developed the so-called generalized equation of three moments. This has the familiar coefficients 1; 2; 1; and  $\frac{1}{4}$ , replaced by long strings of trigonometric functions dependent on the amount of compression. We can now find the resultant bending moment at every point with the resultant deflection at each point along the beam, with full allowance for column effect. There is also a graphical method which applies to a spar with any kind of taper.

Another specialized structural problem is that of the tapered strut. There again has been provided an incentive for great development of the general theory of the tapered column in the last five or six years. We can now determine the load that a tapered strut will carry, and also what is the most economical form of strut — one which will not add unnecessary weight. We have charts which enable us to read off directly the end and center diameters and sectional areas along the strut for any length and load.

The first step in any structural design is of course to find out what stresses exist, and the second, to eliminate the things that are unfavorable. For instance, one of the most unfavorable things is the existence of deflection moments, or column moments, so some designers camber their spars initially, so that the overloaded spar will straighten out and no column moments result. Extra moments also come from eccentricity of attachment of the fittings. If a metal plate is bolted to the spar to attach wires and struts you will get a certain eccentricity. That sometimes modifies the bending moments as much as 25 per cent. There again you can either calculate it or eliminate it, and the only way of eliminating it is by hanging everything on one movable axis, making a true pin joint.

Now analysis is all very well, but one would like to get a check on it also. That is supplied by building the complete structure full size and loading it. One doesn't want to do that with a big machine that has taken years to build, but there are perfectly proper methods of test for small airplanes. Sand or shot are loaded on the structure, distributed over the surface in a prescribed manner corresponding to what experience has taught us the machine should carry in service. The tail surface of a fast airplane must sustain 30 lbs. per square foot without complete failure. Sometimes it has been required to carry one-half of that without permanent set.

The racing machines built recently have a speed of 200 miles an hour and carry 15 lbs. per square foot of wing area. They are designed

with a load factor of about fifteen and are tested to a load of 225 lbs. per square foot.

Another special problem is the taking of suitable precautions against secondary failures of various sorts. When using a 60-lb. I-beam in a structure you are pretty sure that if there is a failure it will go as a whole, and will go at somewhere near the stress representing the strength of the material. In airplane structures that is not so, because we don't use 60-lb. beams. We don't use I-beams usually. Tubes or some special rolled or stamped section are generally used. It is very common practice to use 22-gage tubing, or .028 inch wall thickness, with a ratio of diameter to wall thickness up to fifty. In Germany 3-inch diameter tubing has been used with a wall thickness of 1/25th of an inch. This fails by crinkling, without collapse. It simply folds up like an accordion. You could pull it out again in some cases, without actual cracking.

That type of failure occurs at a stress well below the 60,000 or 70,000 pounds per square inch that represents the strength of mild steel, and the actual figure depends on the ratio of wall thickness to diameter. If you want to get a large moment of inertia you must stiffen locally by corrugations. Square tubing is bad, the round is better, but the corrugated is better still. The art of corrugation has been carried to a high point by the British. They have refused to use light alloys and they use alloy steel. They use chrome nickel of 175,000 to 225,000 lb. per square inch, heat treated.

The channel is another section we must keep away from. It will always fail by crinkling along the edges. If the edges are turned in, it greatly increases the compressive strength because re-enforcement is then provided where the stress is at a maximum.

Duralumin is now much used in airplane structures. It is an alloy about 96 per cent aluminum with the rest copper manganese and magnesium. It weighs about the same as aluminum and has the strength of mild steel, that is after it has been heat treated. It heat treats by prolonged seasoning, alone. After it is heat treated, but before seasoning, you can work it. It is very convenient to be able to drive rivets in this material when they are soft and then have it harden up itself.

Modern engines have been built of about 600 h.p. and weighing under 1,000 lbs. About 1.2 lbs. per h.p. dry is the best done so far. The time when the term "dry weight" will be obsolete, when water-cooling will be driven out by the air-cooled engine, may yet be long in coming, but air-cooling certainly continues to gain. The radial form of air-cooled engine is more reliable and less bulky. These engines

have come in with broken connecting rods, broken pistons, almost any other element nonfunctioning, and still continuing to run. The radial has another advantage in that it can be overhauled piece by piece. Whenever the mechanic has spare time he can take off a cylinder and do the necessary work on it and check it off, and the next time he has time to spare he can take off another one. The overhauling can be done intermittently.

"V" engines are now being run inverted. The advantage is that you get the propeller higher from the ground and can change the shape of the body. It gives greater clearance.

Let us now consider the commercial developments of the present time. I discussed air transport in Europe three years ago, before the Affiliated Technical Societies of Boston. I can now talk of it in America. It is coming to be a reality here, although not much is being done with carrying passengers, for various reasons, some not entirely valid. We are carrying mail, and in addition to the New Brunswick to the Golden Gate line, which has been operating for the last five years, the last two by night and by day, there is the overnight service between New York and Chicago, operated by the Post Office Department, and there are now outstanding twelve contracts for routes operated by private enterprise, carrying mail and getting 80 per cent of the revenue. Of those twelve about six have actually started. One, from Salt Lake City to Los Angeles, has been regularly operating about three weeks. It takes forty-eight hours for mail to travel from Los Angeles to New York by this route. The plane leaves Los Angeles in the morning and makes connection in Salt Lake City in the afternoon and arrives at New York about four the following day. There is another from Puget Sound to Elko, Nevada; another from Chicago to St. Louis; another from Chicago to Dallas, Texas. There is one from Detroit to Chicago, Detroit to Cleveland, and there has been a line operating from Boston to New York since the first of July. Then in the South there is one from Atlanta, via Jacksonville, to Tampa, Fort Myers, and Miami, and one to New Orleans. There is another from Seattle to Victoria.

Since the first of July it has been possible to mail a letter in Boston at 10 P.M. on Tuesday evening and get delivery in San Francisco, Los Angeles, Portland or Seattle, Thursday evening. Or, mailing at 5 P.M. you can get delivery in Chicago at 8 o'clock the next morning, in St. Louis about 10.30, in Wichita about 2, in Dallas, Texas, late that afternoon.

The success of an air line lies on the ground. The organization of the permanent way, the landing fields, methods of lighting, etc., all



offer problems for the civil engineer. The great success of the air mail from New Brunswick to Rock Springs, more than 2,000 miles, has been due to the method of lighting the air way, along which there is a beacon every 20 miles to guide the pilot on his way by night. There is a motto graven in stone above the portal of the Post Office in New York which was put there long before the days of the airplane, but which seems to apply marvelously to it:

Neither snow nor rain, nor summer's heat, nor gloom of night can stay these couriers from the swift completion of their appointed rounds.

### Discussion

QUESTION: What recent instruments are there to tell the pilot whether he is holding his equilibrium in a mist? I have heard that sometimes the plane would be practically on edge.

PROFESSOR WARNER: I think those stories have been a trifle exaggerated. It is true you can go into a very sharp turn. We have a gyroscopic turn indicator that we use. The compass is not much good for that. It takes too long to respond. The turn indicator is very prompt and definite.

As for finding one's way in a fog, that is the outstanding defect in airplane flying. There is no way of overcoming the effect of fog. You can always see bodies of water at night, for example. But when there is a fog it is impossible to fly. Of course it can be partially overcome by directional radio and other means. In Europe this means has been quite generally used, but directional radio is not sure enough to bring the pilot right on to the landing field. It can bring him perhaps within a mile of the field.

QUESTION: Of what material are the propellers?

PROFESSOR WARNER: The majority are still of wood. This probably will not be true, however, a year from now. There is a rapid change towards metal. Duralumin is being used for high-speed planes and the low-speed still use wood.

QUESTION: Wouldn't rain interfere with the wooden propeller?

PROFESSOR WARNER: If running at 500 or 600 feet per second it would not have much effect, but if it were running at 1,000 feet per second you would begin to get a lot of erosion. Sometimes two inches are taken off the end of a propeller in this way.

QUESTION: You mentioned the gyroscope. Does this show the difference between the two wing tips?

PROFESSOR WARNER: No. The static head indicator has been

given up. It was not reliable. The gyroscopic indicator is not likely to go wrong.

QUESTION: The gyroscope is the better one at present?

PROFESSOR WARNER: The static head indicator was never used in this country. It was British in design and use.

QUESTION: What is the factor of initial stability of the whole structure when in the air? I mean the center of weight below the center of resistance.

PROFESSOR WARNER: It isn't worth much. You can't properly compare an airplane with a ship. The airplane and the submarine are more nearly comparable. You have to think of the line of action of the force and you don't change that if you tip the airplane. The vertical position of the center of gravity has very little effect. The fore and aft position is more important. We always try to get a moderate degree of stability. If the machine is too stable it is too heavy to fly. It resists being flown at any other than the established speed. It ought to be possible to release the controls for a limited time and have the plane remain on an even keel.

QUESTION: Does the naval plane have more stability than the army planes on account of pontoons?

PROFESSOR WARNER: No. There is a good deal of effect on lateral stability, but no appreciable effect on longitudinal stability. It has a larger moment of inertia and a heavier weight.

QUESTION: For commercial use is the monoplane going to supersede the biplane?

PROFESSOR WARNER: The British use the biplane, the Germans and Dutch the monoplane. The monoplane has some advantages. It is cheaper to build and easier to keep in alignment and maintain. It has the disadvantage that it takes up more space in the hangar.

QUESTION: What is the best surface for taking off?

PROFESSOR WARNER: For taking off, the best is the smoothest. For landing, the best is the softest. Concrete is best for taking off, but it is poor for landing.

QUESTION: How long should the field be?

PROFESSOR WARNER: The minimum safe length for commercial planes is about a 1,500-foot runway. You can get off the ground in about 600 feet and over fences and trees in perhaps 400 feet more. The runways at the Boston Airport are 1,500 feet. They do very well, though it is desirable to lengthen them. Of course if there were anything high very near the end of the runways it would be hard to do it in that length.

The tendency in Europe is to have very large fields. At Berlin

there is a field only eleven minutes from the center of the business district — a field about  $\frac{3}{4}$  of a mile wide and  $1\frac{1}{4}$  miles long, divided into two parts — one for landing and one for taking off.

QUESTION: Has the Amphibian plane been successful?

PROFESSOR WARNER: Yes. Macmillan used this plane very successfully, with an inverted Liberty engine.

QUESTION: I should like to know just how accurately you can measure the changes in vibration of an air ship.

PROFESSOR WARNER: We measure within one-tenth of one per cent ordinarily.

QUESTION: Can you use a really sensitive instrument?

PROFESSOR WARNER: We design our own instruments and we think we can read the loads on the wings of an airplane within 2 per cent. There are other errors that enter into velocity analysis — 1 or 2 per cent generally. As a matter of fact, the errors due to difference in atmospheric condition from day to day are much more important than errors due to vibration. We cannot check them because of atmospheric conditions, because of the varying convection currents.

QUESTION: What was the plane that Byrd used?

PROFESSOR WARNER: A three-engine Fokker.



# OF GENERAL INTEREST

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## THE "ORIGINAL" OF A CONTRACT PLAN

### A Practical Suggestion for Identification of the "Original Contract Plan"

*By Sturgis H. Thorndike \**

A plan today often passes through at least three stages, — plot on drawing paper, tracing, and blueprints.

A construction contract customarily refers to "the plans." Among all the reproductions and duplications of any given plan, *which* is referred to? Which sheet of paper or cloth is "the original" plan?

Note that "original" may be used with two quite distinct meanings. It may mean the first stage in which a document appeared in complete and final form; in this sense, the lead type, or even the typewritten printer's copy, might be considered the original of a whole edition of printed specifications. On the other hand, it may mean the particular document, perhaps one of many similar reproductions, which is identified as the primary standard, and is the origin of authority in cases of doubt. The latter meaning must be the one intended in any signed agreement, such as a contract. It is unfortunate that "original" has these two meanings, but there seems to be no other word in the English language which, on the whole, expresses as well all the desirable connotations of meaning No. 2.

Methods have developed and needs have changed till today the tracing is not very well adapted to be used as such an "original plan." It is frequently the property of the engineer, not of either of the contracting parties. It is needed for constant use; it can hardly be spared to be "attached to" or to permanently "accompany" the other contract documents, or even to be so filed that it will be safe from loss or damage. It is the most convenient sheet on which to record revisions, including the final "revision as constructed;" even if made extremely intelligently such revisions make it difficult to be sure just what was on the tracing at the time the contract was signed with its reference to this tracing as one of "the plans."

A modern blueprint, on the other hand, makes an admirable "original contract plan." It is durable, permanent. It is as truly a "plan" as is the tracing or the drawing paper stage. It enables a contract to be executed in duplicate, triplicate, etc., with no question that the copy delivered to the owner differs in any way from the copy delivered to the contractor. It is singularly difficult to forge, any alterations being at once

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\* Of Fay, Spofford & Thorndike, Consulting Engineers, Boston, Mass.

obvious. It can actually be "attached to" or permanently "accompany" the other contract documents. Meanwhile the tracing is available for all the current and customary needs.

As a practical suggestion: After the tracings are in final contract form, letter "Original Contract Plan" in coarse black pencil diagonally across the title of each; strike off the number of sets needed in executing the contract; and erase the pencil lettering. The pencil lettering will print on each of these blueprints as a "ghost" marking, differentiating these prints from all others, and difficult to forge exactly on any print taken later. In the agreement, in the identification of the contract drawings, state that they are blueprints, X drawings in a set, and that an official set, in which each print is marked "Original Contract Plan," has been received by each of the parties to the agreement. It is not very expensive for each party to file such a set for verification reference only, other sets of prints being provided for current use in the office or on the job. Each party then has complete and exact record of what was on the "plans" at the time he signed the contract. If the engineer acts as clerk of the contract, and he also has a signed copy of all documents and a set of "Original Contract Plans," the probability is further increased that an unquestioned original document can be produced in case of need.

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## Dam Across Rocky River

*(Boston Transcript—July 31, 1926)*

One of the greatest projects ever undertaken in this State will be started in the near future by the Connecticut Light and Power Company to increase the development of hydro-electric power in the State by adding 60,000 h.p. to the company's present capacity. The proj-

ect, known as the Rocky River dam, will create the largest lake in the State when completed.

The new lake will cover over 7,000 acres of land and stretch about 17 miles in length. It will be located in four towns, — New Milford, Brookfield, Sherman and New Fairfield. The irregular shore line of the lake running back into several valleys will be in the vicinity of 150 miles long.

The new dam, to be constructed across the Rocky River by the U. G. I. Contracting Company of Philadelphia, will be built on a site known as Guarding Hill, and will contain 600,000 cu. yds. of material. Its maximum height will be 100 feet and its length 350 feet. It will be an earth dam, with a concrete core, capable of impounding eight billion cubic feet of water.

The watershed of Rocky River is about 40 square miles, and the annual runoff in an average year will fill the reservoir once. The Housatonic River waters, 200 feet below, will be used to replenish the reservoir supply as required. Two centrifugal pumps, said to be the largest ever constructed, will be installed for the purpose of lifting the river water up over the hill to the reservoir, and will be capable of forcing 3,750 gallons per second up the 200 feet and into the reservoir.

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## New Relief Pumping Station

An engineering project that may be of general interest is the proposed storm duty relief pumping station for the Porter Street Area, East Boston.

Preliminary studies are being made for the station itself, to be located on or near the extension of Maverick Street, and for the main conduit from the end of the present overflow in Porter Street, near Cottage Street, from which the following data are available:

The area to be relieved is about 400 acres.

The conduit is 9'-0" wide by 11'-0" high, reinforced concrete, box shape, about 3,800 ft. in length, to carry 560 c. f. s. on a gradient of 1:1336. This conduit will discharge the estimated storm flow by gravity when the tide is grade 4.50 or lower. With storm occurring with tide above grade 4.50 the pumps will operate up to a maximum rate of 560 c. f. s. (363 m. g. d.) against a maximum static head of about 11.5 ft.

The present station at Calf Pasture handles about 180 m. g. d. maximum, and Union Park Street Station about 108 m. g. d.

It is intended to use electric power for the Maverick Street Station and operate the pumps automatically with float control. Coarse screens may be used, but the screenings may be discharged through the outlet when the gravity flow is resumed. The station is to be strictly storm duty, and will operate only to prevent flooding of the sewer system during storm and high tide. All dry weather sewage flow will be taken care of by the North Metropolitan System, as at present. Borings and test pits will be started soon to determine the nature of the foundations.

## Notes on New England Electrical Activities

(1) The Edison Electric Illuminating Company of Boston has decided to enlarge the Edgar station by adding a 60,000-kw. General Electric turbine unit. I. E. Moulthrop, chief engineer, will have charge of the work and the construction will be done by Stone & Webster, Inc. About \$5,000,000 will be expended on this addition. Thirteen million dollars has already been expended at this station, which when completed may attain a

rating of half a million kw. The present addition doubles the electric generating capacity of this plant, which is now one of the most important stations in the New England interconnected network, and will become more so in future. The Cambridge Electric Light Company has recently contracted with the Edison company for greatly increased service, and the town of Reading has also undertaken to buy energy from this company on a substantial scale.

Work is in progress on a transmission tie line between the New England Power Company system at Millbury, Mass., and the Edgar station at Weymouth, via Medway.

(2) The Gulf Island hydroelectric development of the New England Public Service Company is making rapid progress. This is about 5 miles above Lewiston, Me., and the civil engineering details are described in the Engineering News-Record of August 26.

(3) The Jackman hydroelectric development of the New England Public Service Company, on the Contoocook River above Manchester, N. H., is making excellent progress, and Vaughan Engineers are engineers for this job. This is one step in a multi-plant development which will illustrate river flow conservation admirably when completed.

(4) An interconnection is under way between Keene, N. H., and the Manchester, N. H. district to enable the operating companies of the Insull group to take advantage of the diversity in stream flow in the lower New Hampshire and western Maine areas.

(5) All over New England there is great and growing interest in electric refrigeration, and the Electrical World is now completing a nation-wide survey which points to larger sales of this class of equipment in 1927 than ever before. In many New England cities the utility companies report that the cost of operation is less than the family ice bill.

## PROCEEDINGS OF THE SOCIETY

### APPLICATIONS FOR MEMBERSHIP

[September 15, 1926]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

#### *For Admission*

HOWARD, ARTHUR EARLE, East Boston, Mass. (Age 20, b. Chelsea, Mass.) Graduate of High School of Commerce. Has had about one year's work as transitman and chief of party in Florida on subdivision and road work, and some experience in running section lines. At present is transitman with Charles R. Berry. Refers to C. R. Berry, W. W. Clifford, G. W. Cutting, Jr., L. H. Smith.

JOHNSON, CHARLES L., Hanover, Mass. (Age 27, b. Pembroke, Mass.) Graduate of Wentworth Institute, 1920. Time

keeper for S. C. Sperry Company from June, 1920, to January, 1921, and in the office from January to June, 1921; time keeper from June, 1921, to May, 1922, then became foreman on storehouse for Kingston Knitting Company, built by S. C. Sperry Company; has also been superintendent of construction on oil service stations, warehouse and filtration plant, and is at present on a similar plant in Amesbury. Refers to F. E. Leland, W. F. Pike, G. A. Sampson, J. E. Theriault, E. A. Varney.

LINDSTROM, BARTIL WILLIAM, Dorchester, Mass. (Age 25, b. Boston, Mass.) Student at Tufts College, 1920-22, Northeastern University, 1923-24, and Brown University, 1924-26. Refers to J. H. Bowie, J. E. Klam, Harry Lewis, E. P. McSweeney.

WOODRUFF, MORGAN LEWIS, Boston, Mass. (Age 37, b. Pittsfield, Mass.) Graduate of Polytechnic Institute of Brooklyn, with degree of C.E. From June, 1904, to May, 1905, half time as architectural draftsman; 1905-1911 (3 months each year), structural draftsman and machinery layouts; 1912-13, inspector and assistant engineer; 1913-15, with Brooklyn Rapid Transit Company as draftsman and designer, including layout for tracks, grades, sections, construction and costs; 1915-16, designer and estimator for Concrete Steel Company; 1916-17, with Walter Kidder, Inc., Industrial Engineer, as structural designer and inspector; 1917-19, Engineering Corps, U. S. A.; 1919-24, with Chas. T. Main, Inc., as structural designer, surveyor, general design, layout, field engineer, etc.; 1924 to date, with Morton C. Tuttle Company, as structural designer on reinforced concrete, steel and mill construction, plant layout, etc. Refers to A. W. Benoit, H. A. Gray, F. M. Gunby, Erwin Harsch, Clemens Herschel, C. T. Main.



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DAVID A. HARTWELL . Aug. 3, 1926  
WILLARD C. TANNATT, Jr. Sept. 4, 1926

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Highway Curves and Earthwork. By  
T. F. Hickerson. 1st Edition, 1926.  
McGraw-Hill Book Co.

Industrial Fuel and Power. The Affiliated  
Technical Societies of Boston.\*

Hydraulics. By J. N. LeConte. 1st  
Edition, 1926. McGraw-Hill Book  
Co.

Materials of Construction. By the late  
A. P. Mills. 3d Edition, 1926. (Edited  
by H. W. Hayward).\*

Movable Bridges. Vol. 1, Superstructure.  
By O. E. Hovey. 1st Edition, 1926.  
John Wiley & Sons, Inc.\*

Ports and Terminal Facilities. By R. S.  
MacElwee. 2d Edition, 1926. McGraw-  
Hill Book Co.

Railway Engineering and Maintenance  
Cyclopedia. 2d Edition, 1926. Sim-  
mons Boardman Publishing Co.

Railway Trackwork and Maintenance.  
By E. E. R. Tratman. 4th Edition,  
1926. McGraw-Hill Book Co.

Steel Structures — Stresses in Simple  
Structures. By L. C. Urquhart and  
C. E. O'Rourke. 1st Edition, 1926.  
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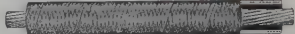
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Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.  
Engineers' Society of Western Pennsylvania, William Penn Hotel, Pittsburgh, Pa.  
Louisiana Engineering Society, State Museum Building, Jackson Square, New Orleans, La.  
Montana Society of Engineers, Butte, Mont.  
Rochester Engineering Society, Carnegie Building, University of Rochester, Rochester, N.Y.  
Technology Club of Syracuse, 1158 Onondaga Hotel, Syracuse, N. Y.  
Vermont Society of Engineers, Northfield, Vt.  
Western Society of Engineers, 1735 Monadnock Block, Chicago, Ill.

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